Basic Electric Circuits
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Module 3:
Network Theorem 1
Lecture 12:
Source Transformation

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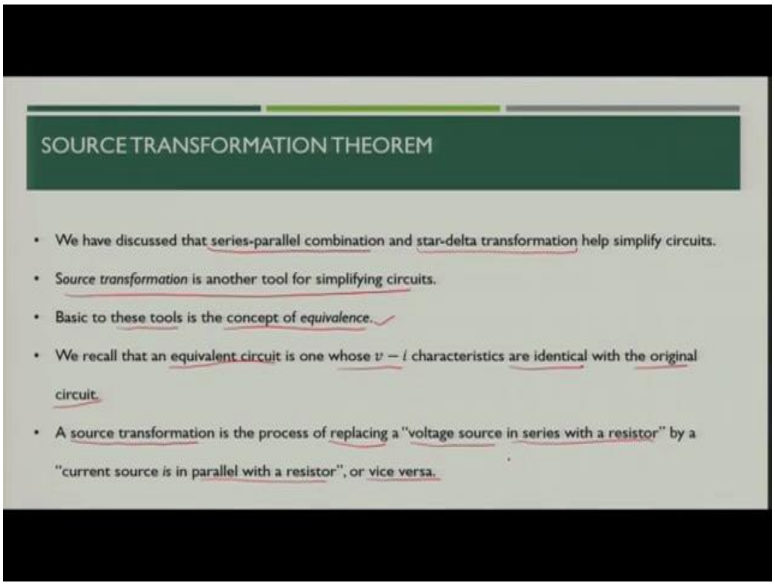

Namashkar, so today in this session we will discuss about the source transformation. What do we mean by source transformation? When we discussed the series parallel combination of the circuit in the previous lecture, we also discussed the star delta transformation we came to know that with the help of these two techniques we can solve the circuit very easily. In case of a series parallel combination we discussed that when the elements are in series or in parallel voltage division and current division works.

Similarly, in the lecture on star delta transformation we discussed that if the circuit looks very complex and if you can figure out that there is a pattern for either star or delta then you can try star delta transformation and make the circuit simpler. In these two ways we discussed in our previous lecture, how you can simplify the circuits. In the same way today, we will discuss how source transformation can help you to resolve the circuits and solve the circuit with the help of these particular techniques.

So, source transformation would be considered as a tool which uses the concept of equivalence. What do we mean by equivalence? Let us first understand what is equivalent circuit, so equivalent circuit is the one whose voltage current characteristics are identical with the original circuit so, that means that if you have V-I characteristic identical for two circuits you can say that both one is equivalent circuit of the second one. And this property of the circuit is called equivalence.

What is the source transformation? Source transformation is the process of replacing a voltage source which is having one resistor in series by a current source which has one resistor in parallel or that can be vice versa, means, current source in parallel with the resistor can be replaced by voltage source in series with the resistor. So how we will do it.

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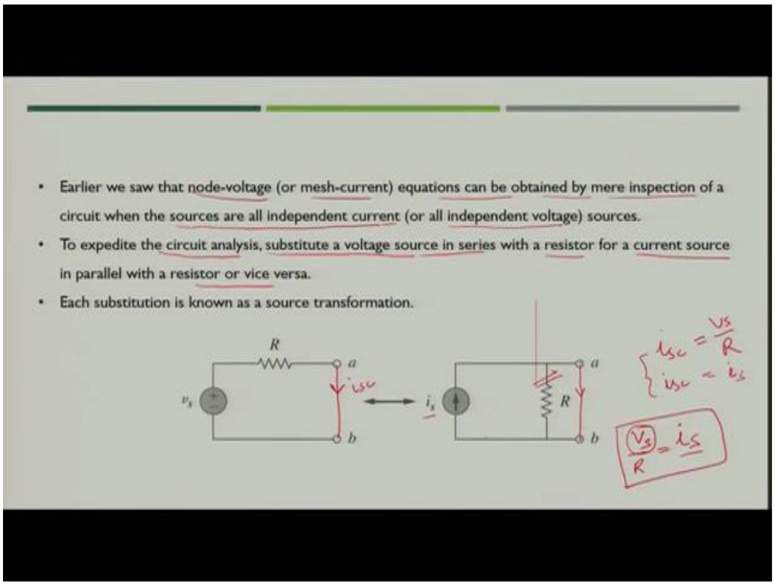

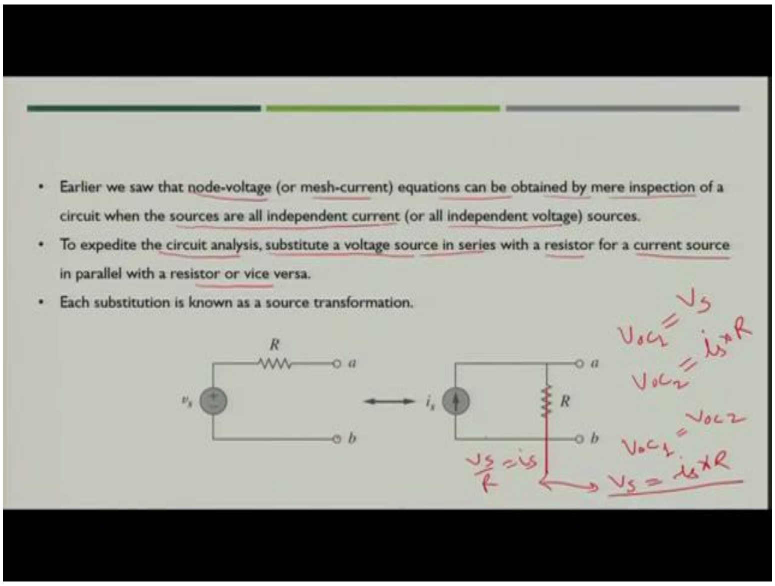

Let us understand, in case of node voltage or mesh current method the equations we were obtaining were, simply with the help of circuit inspection. We were seeing the circuit and identifying basically the assigning the mesh current in the various meshes and then can to find out what would be the value of mesh current. Similarly, a node voltage we were assigning voltage at the node and using Kirchhoff's voltage and current law we were trying to identify the node voltage value.

So this was basically what we were doing with the help of either independent current or independent voltage source or dependent current as well as dependent voltage sources. Suppose we want to expedite our circuit analysis we can add the voltage transformation also. We can speed up our circuit analysis process by substituting a voltage source in series with resistor for current source in parallel with resistor or vice versa.

So, if you see the figure between terminal a and b you have one series resistance R and one voltage source v_s is connected now, the source transformation technique says that if you have voltage current relationship at node a and b same for both of the circuits it means that this can be represented as an equivalent circuit using one current source in parallel with resistance R.

Now, next question would be how will we find out the value of v_s in terms of i_s or i_s in terms of v_s or what will happen to these two resistances, whether both will remain same or those are going to change. So in this particular technique we will try to understand that when we will do the source transformation how the value of the various sources vary, that may be from voltage source to current source then we have to find out the value of current source and if it is from currents to voltage then we have to find out the equivalent value of voltage source and then what would be the value of resistances connected in series or parallel.

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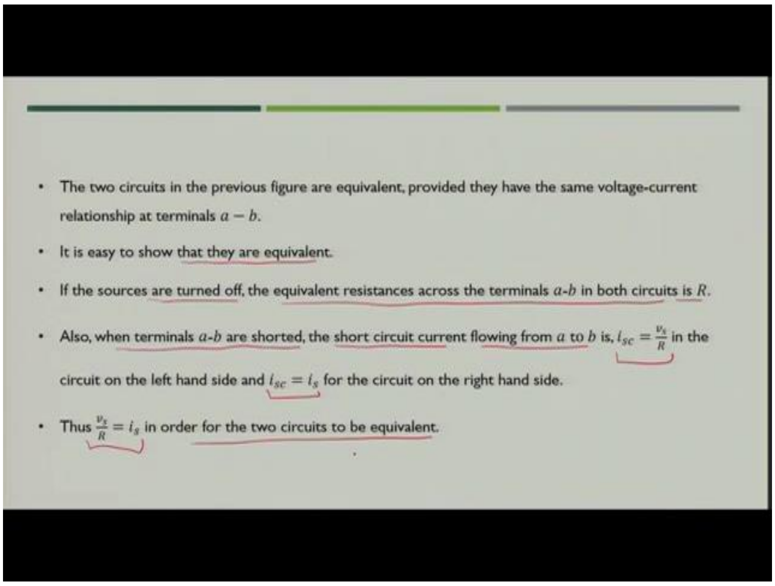

Now, we know that it is very easy to show that these are equivalent what we will do, we will first turn off the source and we will find the equivalent resistance across the terminal ab, so if you see this circuit switching of the source means what, switching of the source means if you have a voltage source you will simply make it as a short circuit and if you have a current source you will make it an open circuit.

So if you see this case and you are trying to find out equivalent resistance across ab when voltage source is short circuited you will see equivalent resistance is R. Similarly, in case of current source if you make current source open circuit is it is disconnected from the circuits then again, the equivalent resistance would be R. So, what will happen when we analyze both the circuits, we will see that equivalent resistance across the terminal ab, will remain same, that is R.

So that would be in both of the cases now, if you are making short circuiting the terminal a and b what would be the value of short circuit current flowing through, flowing from a to b. Let this circuit once again when the circuit is same as it was previous the thing which we have to do now, is that you have to short circuit a and b and your objective is to find out the value of this current, short circuit current.

Suppose if it is i_{sc} so what would be the value of i_{sc}, i_{sc} would be simply, $\frac{v_S}{R}$. Now in this case if you are short circuiting a and b what will happen, this will be in that case neglected so the short circuit current flowing from a to b would be equal to i_s so here we will represent with the same circuit like is given in small form so now, as we discuss that when we are creating the equivalent circuit its property should remain same. That means that short circuit current should be same in both of the cases.

So what do we get from here? We get from here

$$\frac{v_s}{R} = i_s$$

So, this will give you the idea that when you want to do the source transformation how the current source would be related to voltage source, so this we got with the help of circuit and now we found that this is the relationship between voltage and current sources when we are doing the source transformation.

So, we got the voltage relationship as well as resistance relationship. For resistance relationship we try to find out the equivalent resistance across the terminals and for the current and voltage source relationship we just saw, when we short circuit a and b what would be the value of the current flowing through the short-circuited terminal.

Now, instead of short circuit suppose if you are asked, if you are verifying the same concept with the open circuit because short circuit and open circuit are both the characteristic of the circuit, so in case of open circuit what will happen what would be the open circuit voltage across a and b? Open circuit voltage across a and b would be v_s. Similarly, in this case what would be the open circuit voltage, open circuit voltage would be $i_s R$ now as per property if you see that both of the circuits are equivalent, your v_{oc} for first circuit or v_{oc} for second circuit should be equal.

You get v_{s} is nothing but $i_s R$ so, this is the same thing which you got in previously, i.e.,

$$i_s = \frac{v_s}{R}$$

You can cross verify that whether it is short circuit characteristic or open circuit characteristic the circuit is equivalent because it is giving the same output. So now, we have established the relationship between voltage source and current source in both of the equivalent circuit.

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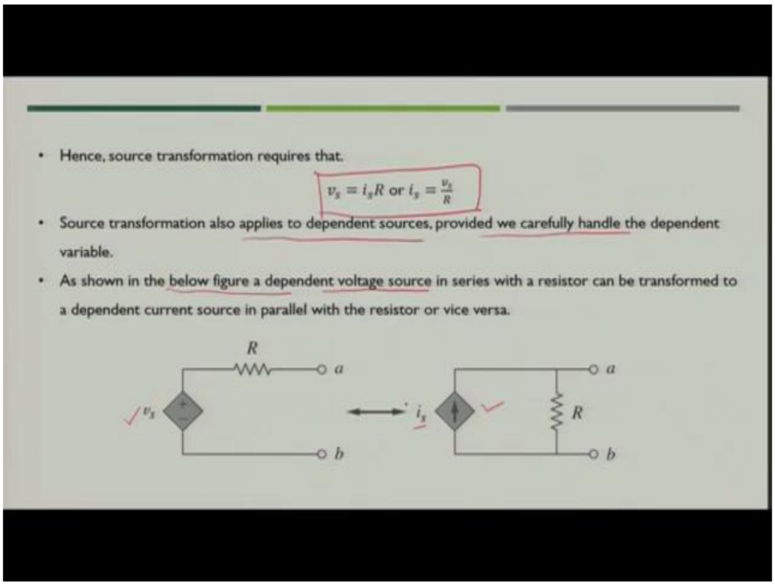

We can summarize the relationship between the voltage sources and current sources would be

$$v_s = i_s R \text{ or } i_s = \frac{v_s}{R}$$

Now, source transformation can also be applied to dependent sources that maybe the dependent voltage source or dependent current source but, this we have to handle carefully because the dependency of various sources from the any voltage or current variable through some other element. Because of this dependency we have to be very careful that how you will handle the source transformation. When we do source transformation and you see dependency with the resistance flow, that particular resistance cannot be considered for the source transformation so that is something which we have to be very careful now. Let us see this circuit below as we saw in the previous case, in this case also you can establish the relationship, that, if voltage source in series with resistance R, it can be represented equally as current source in parallel with resistance R.

In this case voltage source would be dependent voltage source similarly current source would also be the dependent current source. And the relationship between these two should be established in such a way that the dependency of these sources is intact.

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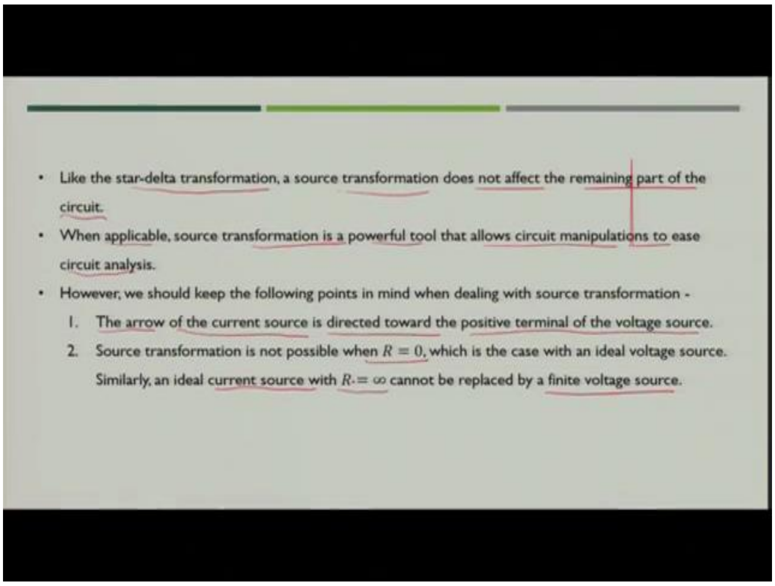

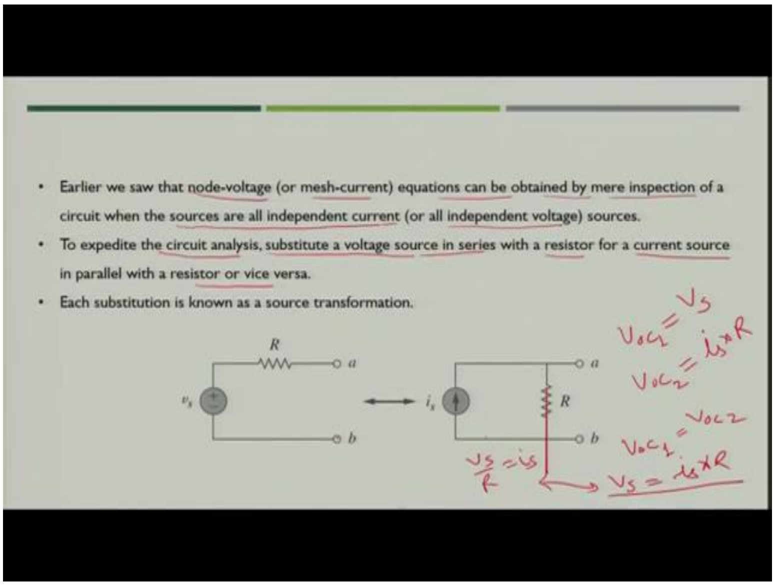

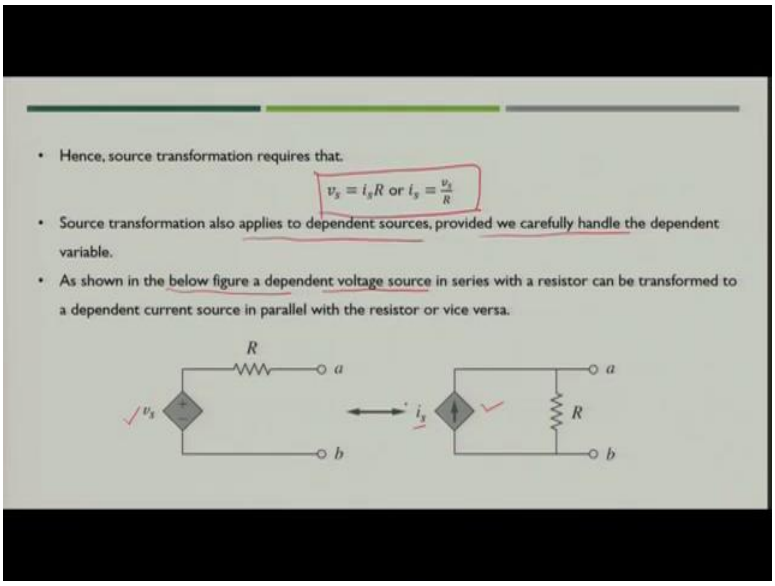

Like in star delta transformation the source transformation does not affect the remaining part of the circuit, so you will apply them for a one particular segment of the circuit. But, this will not impact rest of the circuit so when applicable the source transformation is a powerful tool that allows circuit manipulation to ease the circuit analysis. So, wherever you see the possibility of source transformation you apply them and make the circuit simpler.

Now, you have to keep two points in mind, while dealing with the source transformation. What is that, first is that direction of the current source is directed towards the positive terminal of the voltage source. Source transformation is not applicable when R is equal to 0, in case of the voltage source. So, if you make R is equal to 0, this will become an ideal source. If you make R is equal to 0, then this will become ideal voltage source and if you make R is equal to infinity, this will become ideal current source. So ideal voltage source and ideal current source cannot be transformed from voltage to current or current to voltage so, this also we have to keep in mind when we are doing the voltage or current source transformation. Why, because when you have ideal current source you cannot replace with any finite voltage source so, that is why, it is not applicable when the voltage and current sources are ideal.

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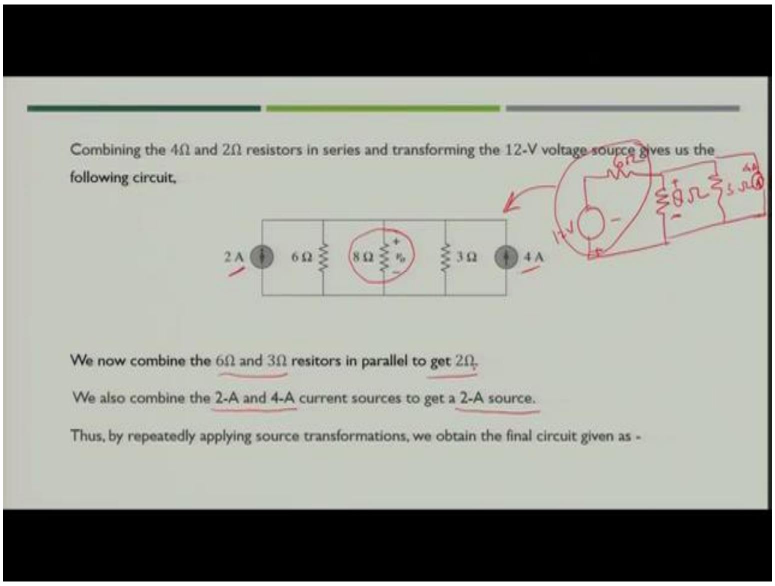

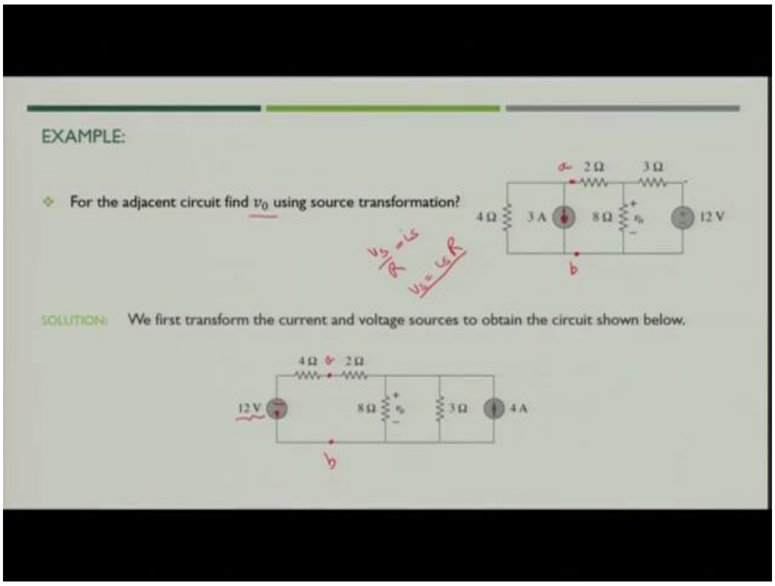

Now let see one example so that you can understand the source transformation concept, now suppose if the circuit is given like this, and you are asked to find the voltage v_0 which is across 8 ohm. How you will solve now? Let us see first the segment. Let us say that this is terminal a terminal b and the left side of this terminal is one current source and in parallel with that there is one resistance so, this is similar to what we discuss previously that this is the current source in parallel with resistance which is an ideal candidate to be transformed into voltage source in series with one resistance.

So, what we discuss what was the value of $v_s = i_s R$. So, this will become 12 volts. Now, you have got the value of voltage what should be its polarity since, current is down ward so, your polarity will be plus now, what would be the value of resistance, resistance value will remain same but, now it will be in series.

So, across ab your updated circuit would be like this. Next you can see easily that 4 ohm and 2 ohm resistances are in series so you can club both of them and you will get circuit like this where you have voltage source in series with 6 ohm resistance and then you have 8 ohm resistance, so we have to find out the voltage across this and then the rest of the circuit, so that is the 3ohm resistance, and the current source of 4 ampere.

Now, if you see this this is again a candidate to be transformed into current source because here seeing that there is one voltage source of 12 volts in series with 6 ohm resistance. So, what we will do, we will simply transform the voltage into current that is if you see a voltage in series with 6 ohm resistance is equivalent current would be 2 ampere. And then there will be a resistance in parallel that will be 6 ohm resistance.

So now, you have got updated circuit from this if you see this circuit you can easily see that there are two current sources in parallel and three resistances in parallel. So you can club these two current sources and these two resistances while you have to leave this resistance intact because you need to find out the voltage across 8 ohm resistance so, what will happen, now if you club 2 ampere and 4 ampere current sources you will finally get 2 ampere current source and if you club 6 ohm and 3 ohm resistance you will get finally 2 ohm resistance.

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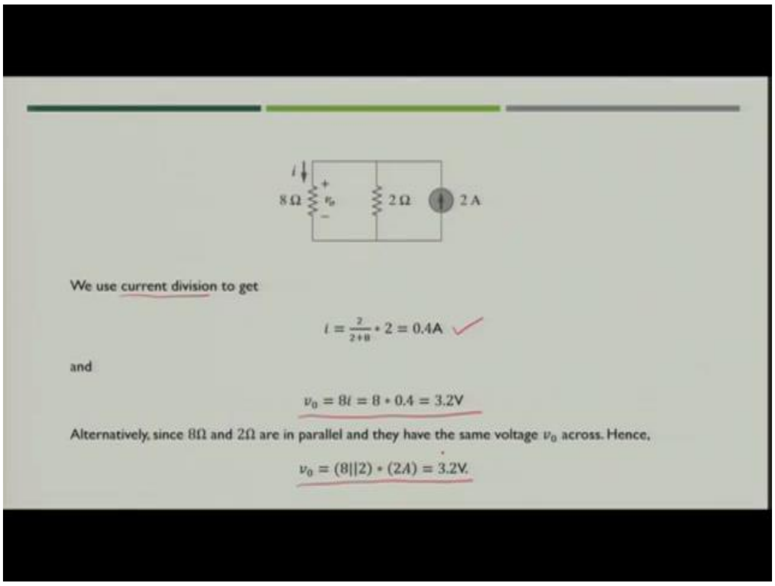

You finally get a very simple circuit where you have 2 ampere current source and 2 ohm resistance in parallel and 8 ohm resistance across which we have to find out the voltage v_0. So, just simply use current division we will get current across 8 ohm resistance as 0.4 ampere and then voltage v_0 is nothing but 8 into current flowing through this and you will get 3.2 volts. Similarly, you can also see that is voltage across this would be same so you can club both of them and find out also the voltage v_0 so, in both of the cases you will get the same voltage.

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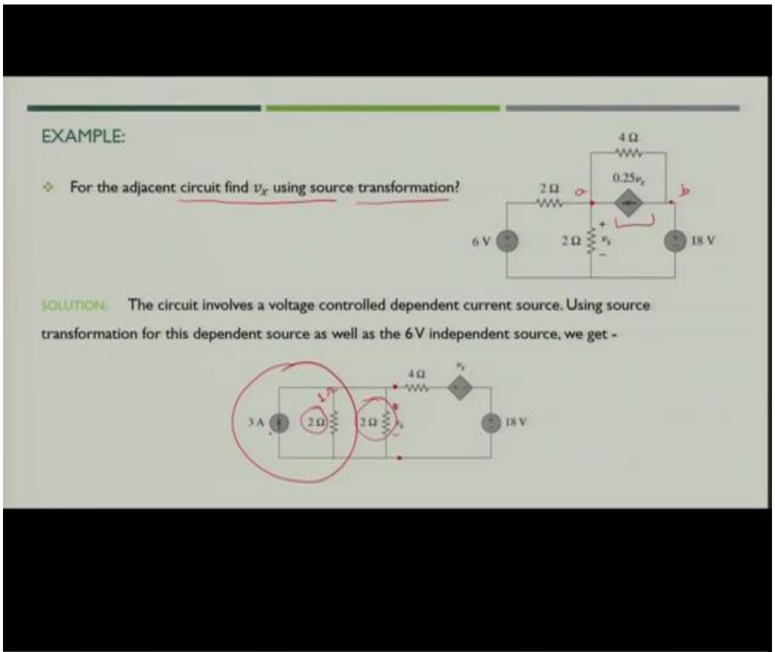

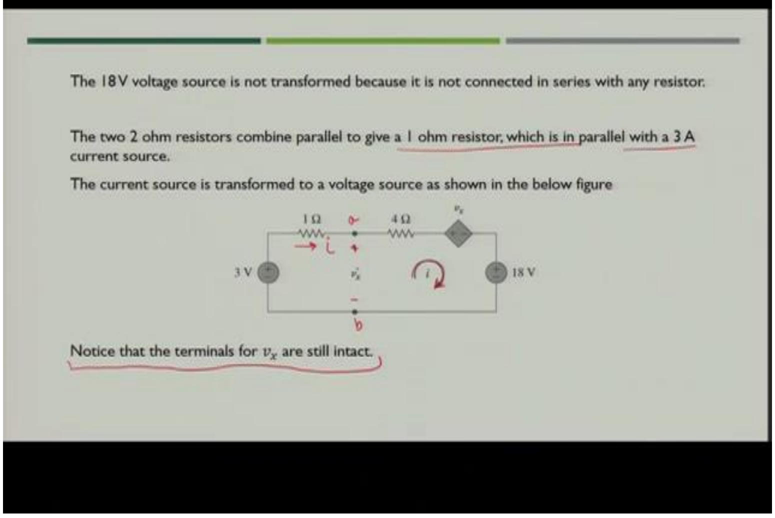

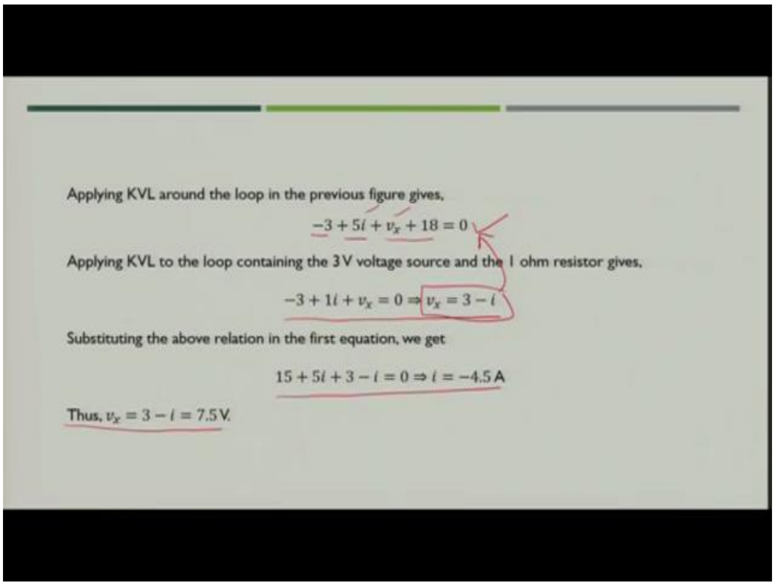

Now, let us see a slightly complex circuit where we have one dependent current source. How will you use source transformation in this case so, you will see this particular segment of the circuit, if you say this is terminal a and b so what you are see, this is one current source in parallel with one 4 ohm resistance so, this can be converted into equivalent voltage source v_x and in series with 4 ohm resistance. So, if you multiply we will get v_x as a voltage source in series with 4 ohm resistance and we have to find out the voltage across v_x across 2 ohm resistance.

Now, v_x the voltage across this is depending upon the voltage source value is depending upon the voltage across 2 ohm resistance so, we cannot use this for any transformation we have to keep it like, this in the circuit, and rest of the transformations we can do. Now if you see this particular segment this can be again converted into the voltage source.

So, what we get we get 3 volt in series with 1 ohm because 3 ampere in parallel with R in parallel if you club both of them still the voltage will not change because these two are sharing the same voltage, because if you see voltage across 2 ohm, in this case voltage will remain same even if you club both of them. So, you can keep the v_x same and club both of them so, that would be easier for us to understand the concept rather than keeping this 2 ohm intact because now, here we have both resistances in parallel.

So, we club both of them but, we know that since, voltage will remain same so, it is okay for us to do, that particular combination of resistance. So now, we have the 1 ohm resistance equal and the there is one 3 ampere current source. So, when you do source transformation so, since this 2 ohm has become 1 ohm now, finally because you club both of them then 3 ampere in parallel so, what after source transformation what you get you will get 3 volt in series with 1 ohm resistance and then you have the same v_x which you need to find out.

And then you have 4 ohm in series with v_x and then 18 volts which we have in the circuit, now as we discuss now v_x is still intact which is the question that we need to find out the value of v_x so we are okay with the transformations now, what you have to do, you have to use mesh analysis and you apply Kirchhoff’s voltage law across the bigger loop what you will get,

$$-3 + 5i + v_x + 18 = 0$$

The question is we have here two unknown and equation we have got only one, so where we will get this second equation.

If you see the voltage across these two terminals ab suppose what would be the value of v_x. v_x would be nothing but you know that current flowing through this 1 ohm is i which we have considered in the calculation of first loop. We can say $v_x = 3 - i$. So, the same way we have calculated $v_x = 3 - i$ now, this value you can put in the above equation and simplify you will get current as

$$15 + 5i + 3 - i = 0 \Rightarrow i = -4.5 \text{ A}$$

$$v_x = 3 - i = 7.5 \text{ V}$$

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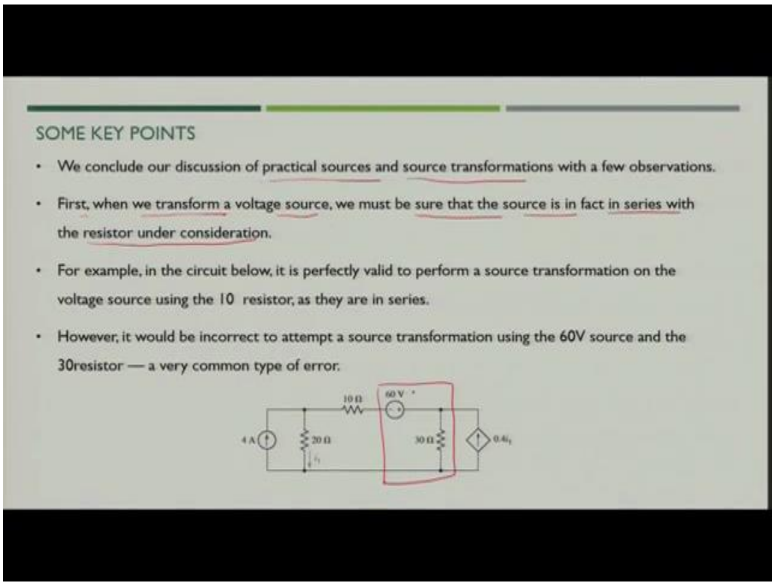

Now, some key points which you have to remember is that, for practical source the source transformation should be considered while keeping these particular aspects in mind, first is that when we transform a voltage source we must be very sure that these sources in fact in series with resistor under consideration, so for example if you see this circuit below it is perfectly valid to perform source transformation to the voltage source and 10 ohm resistance which is in series with voltage source.

So, this you can utilize but, you cannot apply the same source transformation while considering these two elements like 6 volts and 30 ohm because this 30 ohm is not in series with 60 volt source. So, that something which we have to always keep in mind that how you choose the correct candidate for source transformation and sometimes this becomes a very common type of error when we do the source transformation.

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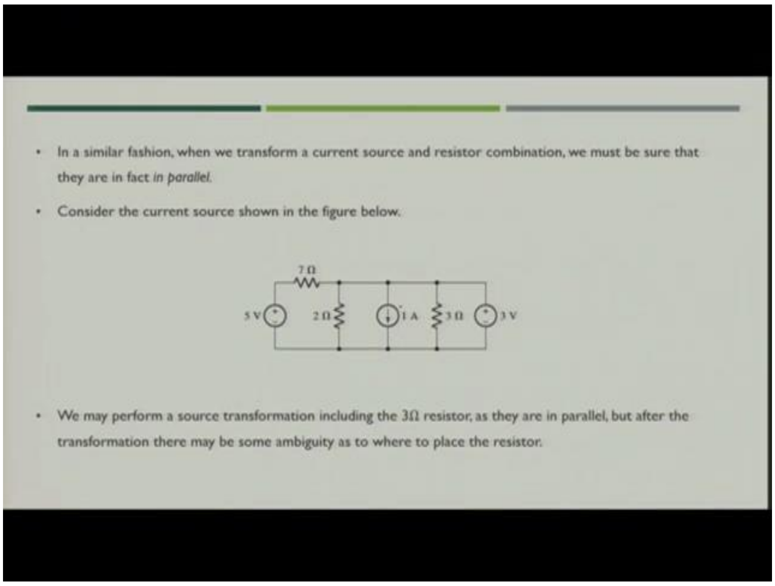

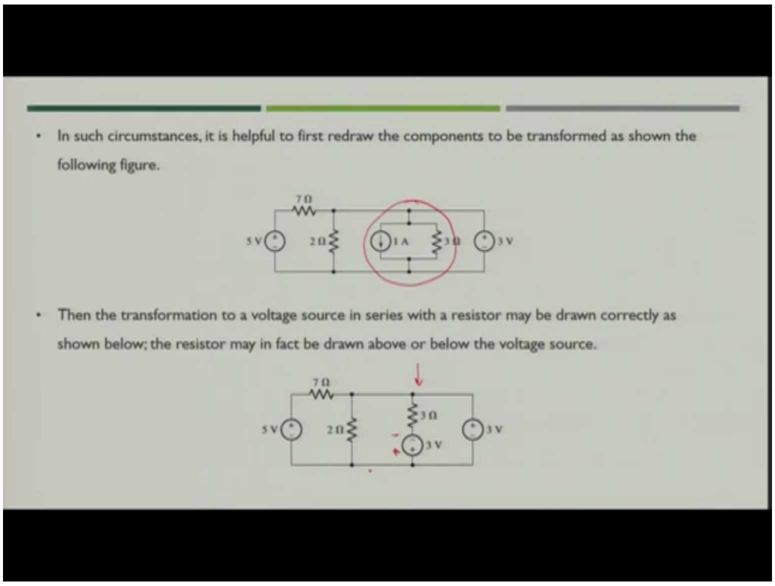

Now next is that in the similar way when we do current transformation we have to always be sure that the current source have at least one resistance in parallel, if you are not sure how it will be looking like you can modify the circuit slightly like here, you see 1 ampere current source is in parallel with 3 ohm so you can rewrite redraw the circuit in this fashion so, that you can easily see that there is 1 ampere current source in parallel with 3 ohm resistance so, when you are sure, then you can apply the source transformation and get the value.

So in this case what we have got, we have got 3 voltage source in series with 3 ohm resistance now, this resistance you can either put above the voltage source below the voltage source it does not have any significance from location prospective so, both would be same either you put up side or down ward the only important thing which you have to remember is that, the direction of current will give you the idea that how the polarity of the voltage source would be define.

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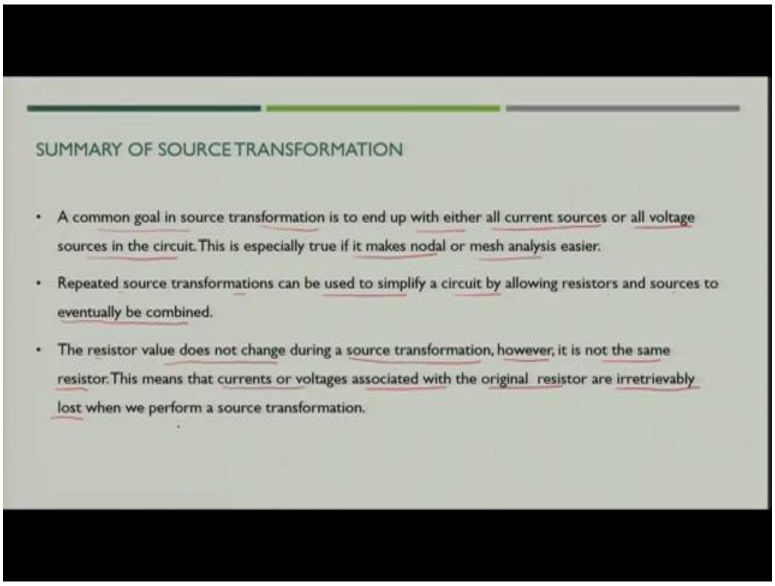

Now in summary what we can say that the common goal of the source transformation is to end of with either all current sources or all voltage sources in the circuit. So that we can easily apply over nodal or mesh analysis, repeated source transformation can be used to simplify the circuit by allowing resistors and sources to eventually be combine. The resistor value does not change during the source transformation this is what we have seen however it is not the same resistor that means that, the current of voltage which are associated with the original resistor are irretrievably lost.

That means that the transformations which you are doing the same 3 ohm resistance will not give you the same output. Means now, the location of 3 ohm resistance have been changed so, in that way you can say that resistor value is same but, its association has been irretrievably lost, it means that you cannot retrieve the output of the resistor until unless you reverted back to the original form. So although resistor value is same but, its value will remain same but, the association has changed.

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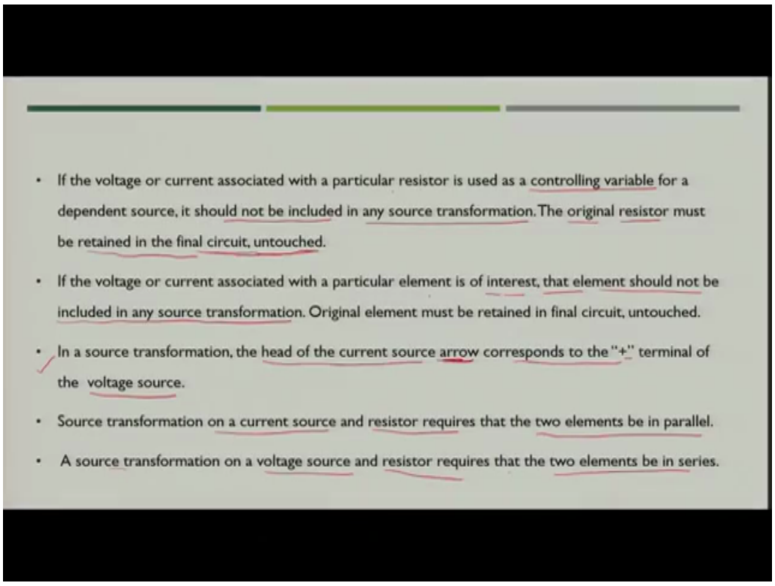

Now, voltage or current associated with particular resistor is used as a controlling variable then what will happen, so in that case it should not be included in any source transformation so, in that case your original resistor must be retained so that at the final circuit when we process the information related to voltage and current and try to find out the variable value, the dependent source parameter is untouched so, generally what happens that when we see the dependent voltage or current sources the current value across a particular resistance or voltage across the resistance would be depending upon the source value would be depending upon those parameters.

So, we try to keep those parameters untouched the voltage or current associated with the particular element is of interest that element should not be included in any source transformation so, suppose even if there is no dependent voltage or current source but, we want to find out the voltage across an element or current through that element, we will not use that element for any source transformation.

Now, in case of source transformation the head of the current source that is the arrow will correspond to the positive terminal of the voltage source, so this is what we have to always keep in mind while we transforming current to voltage source and source transformation of the current source and resistor requires that the two elements should be in parallel and source transformation voltage source is that resistor should be in series with the voltage source.

So, these things which we have discuss we should keep in mind while we do the voltage or current source transformation. So, with this we close our today's session in the next session we will discuss few other exciting concepts of the circuit. Thank You.